

Report to Congress on
Analysis of Wind Resource Locations and
Transmission Requirements in the Upper Midwest

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Executive Summary

The Conference Report (108-357) accompanying the Energy and Water Development Appropriations Act, Fiscal Year 2004, requested the U.S. Department of Energy (DOE) “to work with the transmission industry to conduct a comprehensive analysis of upper Midwest wind energy locations and transmission requirements and to report to the Committees on Appropriations by May 31, 2004.” (H.R. 108-357).

In February 2004, a team composed of staff from DOE’s Office of Energy Efficiency and Renewable Energy (EERE) and Office of Electric Transmission and Distribution (OETD) contacted management of generation and transmission companies in the upper Midwest that have been active in wind energy for their assistance in this analysis. These companies included Xcel Energy (Minneapolis); Basin Electric Power Cooperative (Bismarck, North Dakota); the Midwest Independent System Operator (Carmel, Indiana); and the Western Area Power Administration (Lakewood, Colorado). In addition, interested stakeholders and 25 transmission planners representing 17 transmission providers were contacted. All were asked to comment on the proposed analysis approach by March 12, 2004.

To identify wind resource qualities and locations, DOE used the geographical information system for wind resources at the National Renewable Energy Laboratory. This information suggests a trade-off between more prevalent but less energetic wind resources located relatively close to metropolitan areas that have a higher demand for electricity, and the stronger wind resources that are often located hundreds of miles from the load.

This analysis provides a summary of completed transmission studies in the upper Midwest related to wind energy and identifies ongoing studies. Comments received from transmission planners generally supported the geographical scope of the study and the planned analysis approach.

Principal Conclusions

- The upper Midwest has very large wind resources, with five of the top ten States in terms of wind resource located in this region.
- Generally, the best wind resources in the upper Midwest are in more remote, less-populated areas far from metropolitan areas that have a higher demand for electricity. Current wind economics favor more remote wind resources, even when factoring in the incremental transmission costs to transmit the wind energy to metropolitan centers.
- Transmission in the upper Midwest is generally constrained. In addition, because power generation is often transmitted over long distances to metropolitan centers, the upper Midwest has voltage and stability issues that must be considered. Since it is more economic to transmit wind from remote

areas, developing more wind energy in remote areas may aggravate these voltage and stability issues.

- Large-scale wind development will generally require additional transmission capacity. Wind projects to serve local electric demand, such as the Basin Electric wind projects in North Dakota and South Dakota, will generally not require additional transmission capacity.
- Although the Midwest Independent System Operator (MISO) issued a transmission plan in 2003 that recommends up to \$1.862 billion in transmission improvements to maintain reliability, it acknowledged these improvements would not fully resolve transmission constraints in the upper Midwest.
- As a relatively new organization, MISO's current transmission plans are primarily an accumulation of the transmission and resource plans of individual participants, a bottom-up effort, and is only to a lesser degree at this time a strategic MISO-region wide synthesis of this information, which would be a more top-down approach. DOE supports and encourages MISO's efforts to move toward top-down, region-wide transmission planning with sensitivities focusing on transmission system implications for different regional resource deployment strategies.
- Numerous stakeholders have expressed interest in exploring potential transmission expansion options in order to access remotely located energy resources. In some instances, these stakeholders are collaborating on how to expand the transmission system in the upper Midwest. An example is the Upper Great Plains Transmission Coalition that consists of electric utilities, wind energy generators, and coal companies, among other stakeholders.
- MISO is exploring potential transmission expansion options that, if implemented, could resolve some of the region's transmission constraints and access lower cost wholesale energy resources, including wind. However, the question of who pays for transmission expansions will be a major barrier to large-scale exploitation of the abundant wind (and coal) resources in the upper Midwest. Until the question of who pays (which includes issues of cost recovery and cost allocation) is answered, there likely will be no major expansion of transmission capacity to support wind energy development in the upper Midwest.
- Long-distance transmission expansion may take several years to permit and build. Interest has been expressed in short-term and mid-term options, such as strategic upgrades at key constrained locations, and tariff changes, such as flexible firm transmission service, that could make more transmission available.

- Transmission planners identified some needed information and studies. DOE and the wind industry can provide the information identified by transmission planners to ensure that wind energy can be integrated into the electric system.

Introduction

The Conference Report for the FY 2004 Energy and Water Development Appropriations Act (H.R. Rept. No. 108-357), stated that:

"The conferees are aware that the potential for expanding wind generated energy to new locations is significant, but further development in the Dakotas and the Upper Midwest is stymied by transmission constraints. The conferees are committed to developing the potential of wind energy in the United States and especially on tribal lands. The conferees direct the Department to work with the transmission industry to conduct a comprehensive analysis of upper Midwest wind energy locations and transmission requirements and to report to the Committees on Appropriations by May 31, 2004".

In February 2004, a team composed of staff from DOE's Office of Energy Efficiency and Renewable Energy (EERE) and Office of Electric Transmission and Distribution (OETD) contacted management of generation and transmission companies in the upper Midwest that have been active in wind energy for their assistance in this analysis. These companies included Xcel Energy (Minneapolis); Basin Electric Power Cooperative (Bismarck, North Dakota); the Midwest Independent System Operator (Carmel, Indiana); and the Western Area Power Administration (Lakewood, Colorado). In addition, interested stakeholders and 25 transmission planners representing 17 transmission providers were contacted. All were asked to comment on the proposed analysis approach by March 12, 2004.

1. The geographical scope of the analysis, i.e., which States compose the upper Midwest.
2. The proposed organization of the analysis.
3. The identification of ongoing studies to support wind and other transmission requirements.
4. The transmission studies needed to fill gaps.

The analysis was jointly prepared by EERE and OETD. OETD leads the National effort to modernize and expand the Nation's electricity systems. OETD also sponsors research and development on transmission reliability that emphasizes real time grid management leading to a more efficient electric power system.

Wind Energy and Transmission Requirements

By the end of 2003, U.S. wind generation capacity had reached over 6,000 megawatts (MW). Although this amounts to less than 1 percent of the Nation's total generating capacity, wind energy capacity has more than tripled since 2000.¹ Continuing advances in technology and economics will further fuel market growth in wind energy. Taller turbines help access better wind resources, increasing energy production and driving down the cost of energy from wind power.

Although U.S. wind energy resources could provide even more electricity from wind energy, many of the best resource areas are located far from load centers. Nationally, the average distance from the top 40 metropolitan centers (where electric demand is strongest) to the very strong wind resource areas (wind power class 6 — 15 miles per hour annual average) is 500 miles, while the average distance to the more prevalent, but less intense wind resources (wind power class 4 — 13 miles per hour annual average) is 100 miles.² Five of the top ten States in the Nation in terms of wind potential are located in the upper Midwest. While the upper Midwest may have very large wind energy potential, it lacks sufficient transmission.

According to DOE's National Transmission Grid Study, which was issued in May 2002, the national transmission system is becoming increasingly congested, and the upper Midwest region is a stark example.³ The region accounts for two-thirds of all calls for transmission loading relief (TLR), according to data compiled by the North American Electric Reliability Council.⁴ Transmission capacity on any given line is often fully utilized, especially during peak periods. Because of these transmission constraints, interconnecting new generation projects without causing more transmission congestion or violations of regional reliability criteria is very difficult. In addition, the upper Midwest is characterized by large generating plants located far from the metropolitan load centers. As a result, the region is beset by voltage and stability problems.

Because of these factors, there is increasing interest in building new transmission facilities and new capacity in this region in order to access new generating resources such as wind. The American Wind Energy Association (AWEA) proposed constructing several 345 kilovolt (kV) transmission lines and two major high voltage transmission lines to deliver wind energy from the upper Midwest to the Western and Eastern United States. AWEA estimates that its "wind pipeline" would deliver 30 to 60 gigawatts (GW) of wind capacity and would cost between \$10 billion and \$20 billion.⁵ In addition, North

¹ American Wind Energy Association. "Boom: Close to Best Year Ever for New Wind Installations. Bust: Expiration of Key Incentive Lowers Hopes for 2004," January 22, 2004. Available at <http://www.awea.org/news/news040122r03.html>.

² National Renewable Energy Laboratory, GIS analysis

³ U.S. Department of Energy. *National Transmission Grid Study*. May 2002. Available at <http://tis.eh.doe.gov/ntgs/reports.html#reports>.

⁴ Jeff Webb, Midwest ISO, Presentation before the National Wind Coordinating Committee's Midwest Transmission Workshop, St. Paul, Minnesota, February 11, 2004.

⁵ American Wind Energy Association. *Concept Description: Trans-Prairie and Interior West Wind "Pipelines."* September 6, 2003. Available at <http://www.awea.org/policy/documents/WindPipeline.pdf>.

Dakota Senator Byron Dorgan proposed a Heartland Wind Energy Pipeline that, among other things, would create a regional compact of northern Great Plains States, including North and South Dakota, Minnesota, Montana, Wyoming, Kansas, and the Canadian province of Saskatchewan, to promote a regional strategy for wind energy development. The compact would work on increasing investment in transmission capacity in the region and promote hydrogen production as a means of storing and transporting wind energy.

However, for a variety of reasons, it may take as long as 10 years to site new long distance transmission lines. These reasons include the time it takes to site and obtain permits for a long-distance transmission line, the large amount of capital that is required, and the time it may take for regulators and stakeholders to resolve questions over cost recovery and cost allocation for a long-distance transmission line. Because of this, other alternatives should be considered as a near-term strategy. These alternatives include strategic upgrades at key constrained transmission locations, increasing conductor size to increase transmission capacity, increasing transmission voltage, or adding other components to increase transmission rating. Another alternative would be to build smaller wind projects to serve local electric customers, such as the 40 MW wind plants built in North and South Dakota by Basin Electric.⁶ Still another alternative would make greater use of existing transmission capacity by using wind energy when it is available and deferring wind energy during times of peak load when access to transmission is needed for other generation. Debate is just beginning over this “flexible firm transmission service,” and, therefore, it will not be discussed extensively in this report.

This analysis is organized as follows:

1. Discussion of the wind resource and availability of wind resources close to upper Midwest load centers.
2. Review of existing transmission studies and summary of results. This section is broken into two parts—one on studies involving the Western Area Power Administration and the other on studies involving other parties.
3. Summary of comments from transmission planners and external stakeholders.
4. Conclusions.

Wind Resources in the Upper Midwest

For the purpose of this analysis, the upper Midwest was defined to include the States of North Dakota, South Dakota, Minnesota, Illinois, Iowa, Nebraska and Wisconsin. With the exception of Nebraska and Wisconsin, newer, high-resolution (0.04 – 1 km²) wind resource data were used for this analysis. However, the high-resolution data used for Minnesota and Iowa have not been validated by the National Renewable Energy Laboratory (NREL). Land use exclusions were applied to the data to eliminate areas that are unlikely to be developed, such as national parks, wilderness areas, urban areas and airfields (see Figure 1).

⁶ FPL energy press release, http://www.fplenergy.com/news/2002/contents/dakota_wind_news.shtml

NREL analysts were asked to develop information about larger cities in the region and their location relative to wind energy resources, as defined on the best available maps. Wind resource classes are defined by average wind power density normalized to a

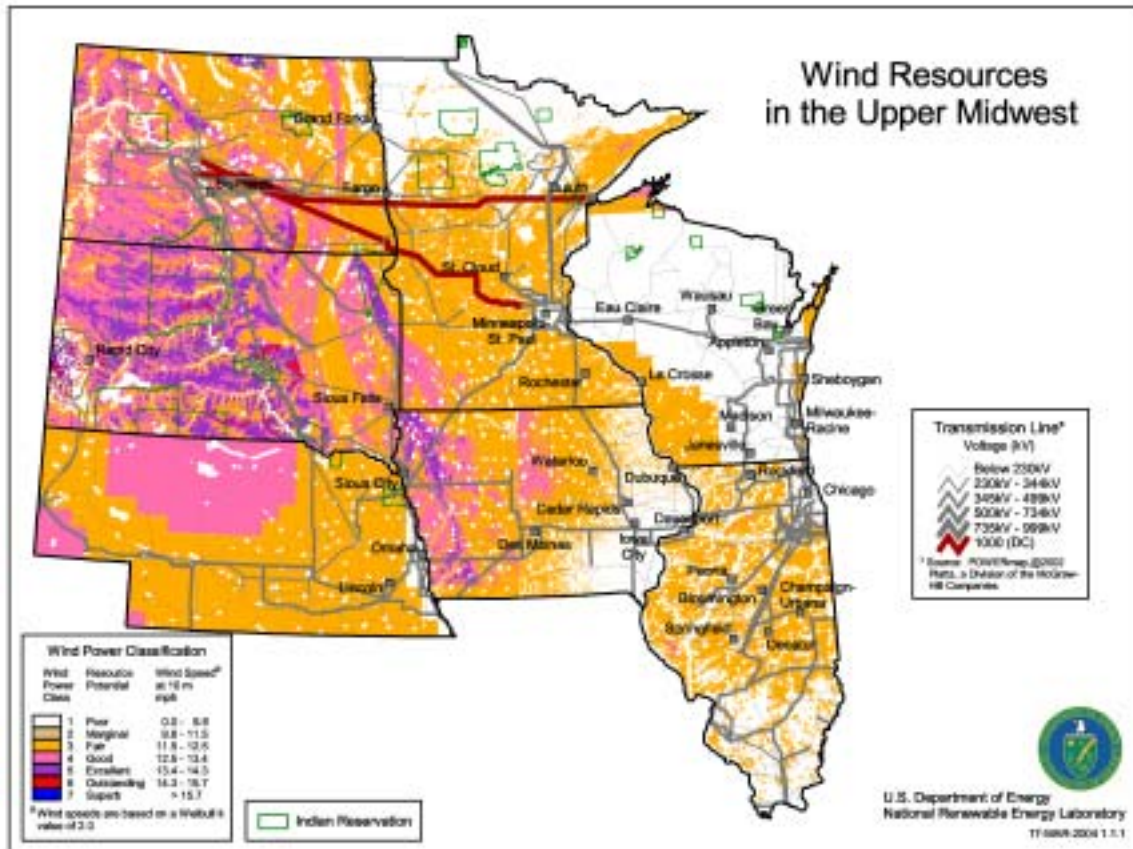


Figure 1: Wind resources in the Upper Midwest

standard height of 10 meters above ground. Class 3 wind resources, with average annual wind speed of 12 miles per hour, are assumed to be marginal for utility-scale wind development and beyond the reach of current technology. Class 4 resources, with 13 miles per hour average wind speed, are considered good and are targeted by the DOE's Low Wind Speed Technology Project with a goal of commercial wind technology capable of generating power at 3 cents per kWh by 2012. Class 4 resources are available in 36 of the 48 continental States. Class 5 resources have an annual average wind speed of 14 miles per hour and are considered excellent wind resources. Class 6 and higher wind resources with an annual average wind speed of 15 miles per hour or greater are considered outstanding.

To illustrate the geographical relationship between load centers and the different classes of wind resources, NREL performed a geographical information system analysis on key cities in each State in the upper Midwest. The analysis assumed 20 percent of the

region's total electric consumption⁷ in 2000 was to be provided by wind energy. The analysis first assumed use of Class 3 wind resources and identified the closest Class 3 resources to that load center, then Class 4 resources were assumed and, so on for each load center independently. A separate analysis was conducted to identify the closest wind resource, by class, to reach all of the load centers in the region as a whole. Space does not allow presentation of the graphical results for each region and State. A sample is provided below to show the most economical wind resources by wind resource class that could serve 20 percent of the electric demand of Minneapolis. This example illustrates that while moderate wind resources may be located close to load centers, the best or most powerful may be located several hundreds of miles away. Analysts used the geographical distance on the map as a surrogate for length to transmission required to move the wind energy to a load center. More information on this analysis and a spreadsheet used for calculations can be found on the NREL website at <http://www.nrel.gov/wind/uppermidwestanalysis>. For more information on national wind resource data collected by NREL, visit <http://rredc.nrel.gov/wind/>.

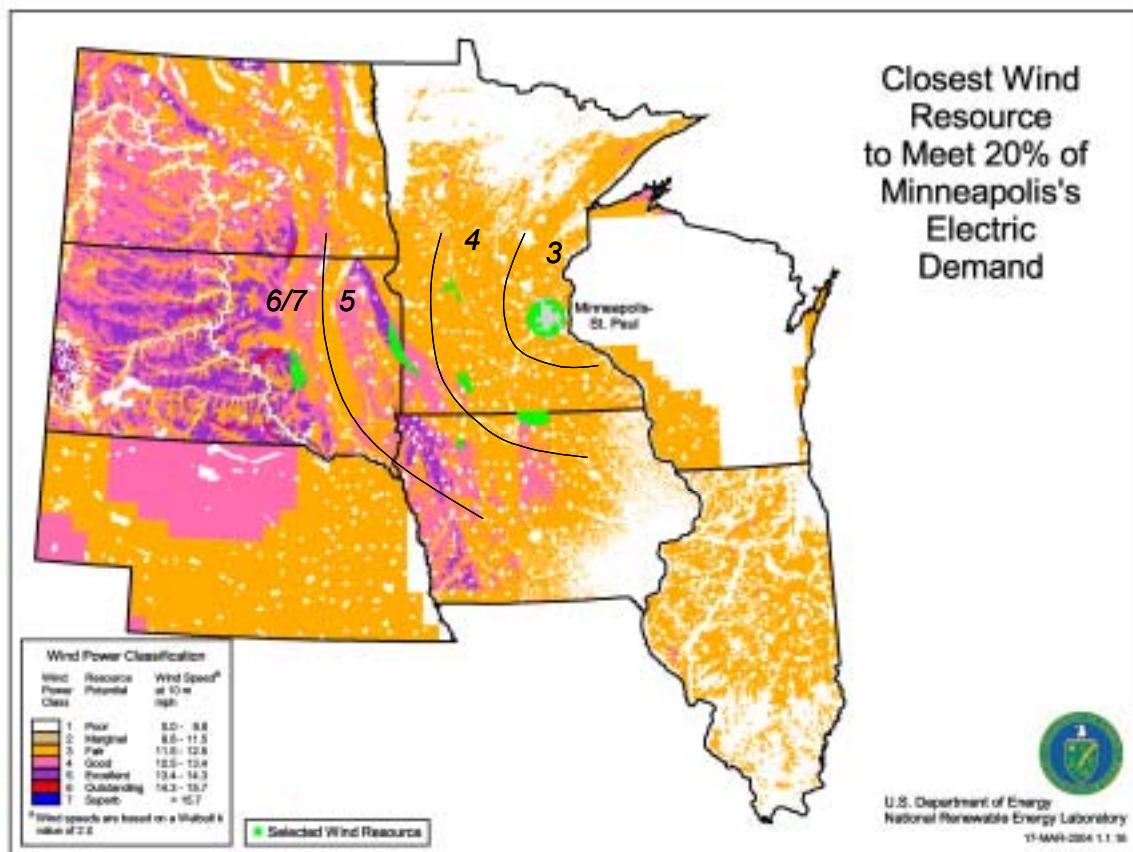


Figure 2. Closest wind resource to meet 20% of Minneapolis's electric demand.

⁷ Energy Information Administration, available at http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls

Transmission Studies Involving the Western Area Power Administration

The Western Area Power Administration's (WAPA) Upper Great Plains Region comprises Montana, North Dakota, South Dakota, Nebraska, Iowa, and Minnesota. This regional office (one of four regional WAPA offices) markets power from eight hydroelectric dams through nearly 7,800 miles of transmission lines.⁸ To investigate modest amounts of wind development in North and South Dakota for export to metropolitan areas, EERE funded and cooperated with WAPA on multiple transmission studies in the upper Midwest. These are summarized below. In addition, in the Fiscal Year 2004 Energy and Water Appropriations Conference Report (H.R. 108-357), Congress requested that WAPA study the placement of 500 MW of wind energy in North and South Dakota. WAPA is seeking public comment on the scope of the study, potential sites for wind projects, and issues in interconnecting wind projects to the transmission grid.⁹

Western Area Power Administration and National Renewable Energy Laboratory, Dakotas Wind Study, February 2000

WAPA and NREL performed a screening study on the interconnection of 150 MW of wind generation at 12 substations, seven in North Dakota and five in South Dakota. The Dakotas have historically been power exporters because of the presence of several large coal power plants within North and South Dakota. Exporting power out of the Dakotas is limited by the ability of the transmission system to tolerate power swings caused by faults on transmission lines and transformers. The study assessed the impacts of wind generation on the local transmission at each of the sites using steady state power-flow analysis on a "N-1" contingency basis, i.e., is the system stable with the loss of a major transmission line. Studies were not done to assess the dynamic response of the transmission system to additional wind generation or of the potential impacts from inadvertent power flow from the wind projects onto constrained transmission interfaces. The study concluded that one site in North Dakota (Jamestown) and two sites in South Dakota (New Underwood and Watertown) could potentially interconnect 150 MW of wind generation without violating regional reliability criteria. In addition, the study found that up to 300 MW of wind could be incorporated at the Watertown substation, and the other nine locations could accommodate varying amounts of wind generation, as restricted by regional reliability criteria violations during a system contingency.

⁸ Western Area Power Administration Upper Great Plains Region. "About Us." Available at <http://www.wapa.gov/ugp/aboutus/default.htm>.

⁹ Western Area Power Administration. "Dakotas Wind Transmission Study Announced," February 20, 2004. Available at <http://www.wapa.gov/media/news/2004/022004DakotasWindTransmissionStudyAnnounced.html>.

ABB and Western Area Power Administration, Final Report on the Transmission System Study of the Upgraded WAPA System, August 2001

This study discussed the steady state and dynamic results from upgrading WAPA lines to interconnect 300 MW of wind capacity at two proposed sites. The first site was near the Jamestown Substation in North Dakota, while the second site was near the Fort Thompson substation in South Dakota. To increase transfer capability at the Jamestown site, the study assessed upgrading a WAPA 230-kV line that runs from Bismarck, North Dakota, to Granite Falls, Minnesota, to a 345-kV line, and incorporated a new 345-kV line from Granite Falls to Blue Lake, Minnesota. To increase transfer capability at the Fort Thompson site, the study considered upgrading WAPA's 230-kV double-circuited lines that run from Fort Thompson to Granite Falls to a 345-kV circuit and a 230-kV circuit, plus the new 345-kV line from Granite Falls to Blue Lake. The study also combined these two options in a separate assessment.

The study determined that the Jamestown upgrades could handle the additional 300 MW of wind generation, although increasing the wind capacity to 600 MW may require system upgrades. The Fort Thompson assessment had similar results. It appeared feasible to combine the Jamestown and Fort Thompson locations to accommodate the 300 MW of wind capacity at Jamestown and the 300 MW of wind capacity at Fort Thompson, although under a single contingency analysis, loss of the proposed Granite Falls-Blue Lake 345-kV line would cause some overloads on other transmission lines. Far more significant, though, was the determination in follow-up studies that the transmission lines could not be upgraded to 345-kV without rebuilding the supporting transmission towers, which raises the costs significantly.

WAPA's 2002 Montana-Dakotas Regional Transmission Study Report, July 2002

In 2002, WAPA commissioned a study to determine the transmission system reinforcements and upgrades needed to support 1,000 MW of new wind and lignite coal generation projects in Montana, North Dakota, and South Dakota. The report examined potential generating projects in both the western and eastern parts of the interconnection. On the western side, five potential sites in Montana were identified, with power being exported to Denver, Salt Lake City, and to markets in the Northwest.¹⁰ On the eastern side, five potential generation sites in North and South Dakota were identified. The study for the eastern side was divided into two phases; one phase of the study identified the transmission requirements for moving power into Minneapolis and St. Paul, Minnesota, and the second phase examined the requirements for transmitting the power into eastern Wisconsin, Iowa and Illinois. In all instances, it was determined that significant transmission upgrades would be necessary to meet transmission reliability criteria before the proposed 1000 MW of new generation could be constructed. The five sites in the study included:

¹⁰ Because this report does not include the region encompassed in the western part of WAPA's study, it is not included in this report. The western WAPA report is at <http://www.wapa.gov/ugp/study/MontDakRgnl/West/Study.htm>.

- Hettinger, North Dakota—500 MW of coal and 500 MW of wind with power transfers to the Minneapolis/St Paul area (Twin Cities) and to the Western Electricity Coordinating Council.
- Jamestown, North Dakota—1000 MW of wind located around Jamestown with power transfers to the Twin Cities.
- Minot, North Dakota—1000 MW of wind located in Minot, with power transfers to the Twin Cities.
- Fort Thompson, South Dakota—1000 MW of wind located around Fort Thompson with power transfers to the Twin Cities.
- Watertown, South Dakota—1000 MW of wind located around Watertown with power transfers to the Twin Cities.

Overall, 21 transmission alternatives were developed and evaluated. The report's authors cautioned that the study was more of a high-level feasibility study to determine the scope and type of transmission reinforcements necessary for new generation at the five sites studied. The report determined that generation at the Fort Thompson and Watertown sites were less likely to require investment in transmission additions or have a thermal impact on existing transmission facilities. However, the Fort Thompson and Watertown sites were more likely to negatively affect transmission flowgates in the southern part of the Mid-Continent Area Power Pool (MAPP) region. These sites, and the Hettinger site, may have more localized problems such as system faults. These problems could be solved by reinforcing the interconnection from the generator to the transmission system or by using special protection systems such as generation tripping protocols. The Jamestown and Minot sites may raise regional stability issues because of the possible interaction with the Manitoba Hydro plants and the large coal-fired stations in Bismarck, North Dakota, and that would require significant transmission investment.

Western Area Power Administration, System Impact Study, Griggs-Steele Wind Power Development Zone, 130-MW Long-Term Firm Transmission Request for 130-MW Wind Generation Addition in Pickert, North Dakota, November 2001 (as amended in February 2002 and April 2002)

In 2001, the Griggs-Steele Wind Power Development Zone (Griggs) requested interconnection service for a proposed 130 MW wind plant near WAPA's Pickert 230kV substation in eastern North Dakota. Griggs also requested long-term firm point-to-point transmission service from Pickert to Xcel Energy in Minnesota. Power system studies are performed whenever a company requests that a generator be interconnected to ensure that reliability is not compromised, and that the proposed generating project can be safely interconnected. Initial studies done by WAPA found that the requested transmission service could be accommodated with facility improvements to the Western/Basin/Heartland joint Integrated System; an increase of 130 MW in Western and Basin's allocation of the North Dakota Export (NDEX) transfer capability, and mitigation

of a number of overloads on other utility transmission systems, mainly in the Minnesota area.¹¹ Subsequent studies further defined some of the overload and other operational issues on other utility transmission systems that could have resulted from the proposed Griggs wind project. A number of proposed transmission expansion options were also evaluated. None of the impacts on other utility transmission systems were eliminated, and in some cases, new impacts were introduced from the proposed transmission expansion options. Ultimately, the MAPP Design Review Subcommittee, which reviews proposed interconnection and transmission requests, recommended approval of the interconnection and requested expansion of the North Dakota Export interface for Western (WAPA) and Basin Electric Power Cooperative (Basin) as long as the wind developer addressed the overload and operational impacts on other utility transmission systems. The wind developer eventually withdrew the project interconnection and transmission service requests. An interconnection study is performed for all projects, including small ones that serve local load.

ABB Consulting, North Dakota to Zion High Voltage Direct Current (HVdc) Transmission Feasibility Study, November 2002, Report No. 2002-10511-1.R1

EERE, Montana-Dakota Utilities, Great Northern Power Development L.P., and Exelon Generation commissioned this study to evaluate the impact of a proposed 800-mile high voltage direct current (HVdc) transmission line from central North Dakota to the Zion substation north of Chicago. The transmission line would primarily transmit lignite coal and wind power generation from North Dakota and western Minnesota to Chicago. As with the NREL/WAPA Dakota Winds study, only the impacts of a steady state power flow analysis were considered, but for both MAPP and for the Mid-America Interconnected Network (MAIN) reliability region. Two different HVdc configurations were considered:

- A two-terminal bipolar HVdc line, rated at 1500 MW, located in the Antelope Valley in North Dakota and running to the Zion substation. The study assessed 1500 MW of wind and two 500 MW lignite generating plants. The capital cost was estimated at \$746.5 million.
- A three-terminal bipolar line rated at 2250 MW, leading from Antelope Valley in North Dakota and Sioux Falls (with a converter terminal connecting to a 345 kV substation at Split Rock) to the Zion substation. Two 750 MW lignite generating units and 2250 MW of wind were assessed. The capital cost was estimated at \$946.5 million.

The steady state analysis used a power flow case based on projected 2004 summer peak-load conditions. The study resulted in a “chicken-and-egg” dilemma between wind generation and new transmission—either build the new transmission and wait for new

¹¹ Western Area Power Administration. *System Impact Study: 130 MW Wind Generation Addition in the Pickert, ND Area and 130 MW Long-Term Firm Transmission Request #283937*, November 2001. See also *Addendum #1* (February 2002); *Addendum #2* (February 15, 2002); and *Addendum #3* (April 2002).

wind generation, or build large amounts of new wind generation and wait for the new transmission to be built.

Other Transmission Studies

Tom Factor (Iowa Wind Energy Institute) and Tom Wind (Wind Utility Consulting), Delivering 2,000 MW of Wind Energy to the Metropolitan Centers in the Midwest, March 2002

This EERE-funded study noted that the better wind sites are typically located in remote areas far from urban cities where electric demand is highest.¹² However, the transmission system in these remote areas generally is constrained and cannot transmit the energy to large cities. The study compared the economics of siting 1,000 to 2,000 MW wind projects near large cities in the Midwest as compared to wind projects of similar size in remote areas. Additional 345-kV ac lines or a 500-kV HVdc transmission system were used to transmit 2,000 MW of wind generation to a metro area. The study incorporated an HVdc transmission system if the distance to the metropolitan area was over 250 miles, because it is generally cost-effective over long distances. Otherwise, the study used several new 345-kV lines to connect the wind generation into the transmission grid. In all cases, some reinforcements to the existing transmission system were needed to accommodate the wind power. To minimize these reinforcement costs, wind power was curtailed at times in the study if certain contingencies occurred on the existing transmission system, such as the loss of a transmission line. The study determined that the amount of curtailed wind generation might average 1 percent to 2 percent of the total annual wind generation and estimated that the necessary transmission upgrade costs to accommodate 2,000 MW of wind ranged from \$38 million to \$759 million.

In general, the study found that it is more economical to build the wind project closer to a metropolitan area than transmit wind energy via a dedicated HVdc line. However, if the HVdc line is used to carry power from other generation sources in addition to wind energy, it may be more economical to build the wind project in more remote areas. In addition, the authors found that in some cases, wind speeds are so low near metropolitan areas that it was more economical to build the wind project in remote areas with higher wind resources and transmit the wind power to metropolitan areas.

Clipper Windpower, Rolling Thunder Transmission Project, 2000/2001

Clipper Windpower is a wind developer with planned and operating wind projects across the country. Clipper envisioned a large HVdc transmission line that would carry 2,000 to 3,000 MW of wind from North Dakota or South Dakota roughly 600 miles to major metropolitan areas such as Chicago. Clipper would head a consortium of companies and be the lead developer, with five to seven other developers taking shares of the project.

¹² Factor, Tom; Wind, Tom. *Delivering 2,000 MW of Wind Energy to the Metropolitan Centers in the Midwest*. Iowa Department of Natural Resources. March 2002. Available at <http://www.state.ia.us/dnr/energy/MAIN/PROGRAMS/WIND/documents/Metro%20Wind%20Non-Technical%20Version.pdf>.

The transmission part of the project would be a separate merchant company on its own, mostly serving the wind developers but also potentially serving other generators interested in transmission as well. Clipper estimated the transmission project alone would cost \$850 million, and the pre-construction study costs for transmission and generation could be \$20 million or more. Because of difficulties in finding investors and buyers of the wind power, the project never proceeded past the conceptual stages.

Synapse Energy Economics/Leighty Foundation Study of Converting Wind into Hydrogen

In 2000, as part of a larger report on encouraging clean energy in the Midwest, Synapse Energy Economics, a consulting company in Cambridge, Massachusetts, prepared a report for the Environmental Law and Policy Center on the feasibility of converting wind energy from wind-rich North Dakota and South Dakota into hydrogen. The hydrogen would be transmitted as pipeline gas to large urban areas such as Chicago, to generate electricity using fuel cells.¹³ An alternative scenario was examined where wind energy would be transmitted to Chicago via new transmission lines. There, the energy would be converted to hydrogen (using off-peak power) and stored with the hydrogen converted into electricity during on-peak periods. For both scenarios, 4,000 MW of wind capacity was to be constructed in a single North Dakota wind plant. The study determined that building new transmission would be less expensive than a hydrogen pipeline, (primarily because of the greater material costs for hydrogen pipelines), unless there were significant efficiency improvements and cost reductions in hydrogen and fuel cells, substantial increases in fossil fuel prices, a carbon tax, or a combination of these developments.

Nebraska Power Association, Potential for Merchant Wind Energy in Nebraska, February 2002

This report was prepared as a response to a request from Nebraska Governor Mike Johanns concerning the potential development of wind projects in Nebraska.¹⁴ The Nebraska Power Association (NPA) report studied the feasibility of creating a public entity in Nebraska to plan, develop, finance, operate, and market the output of one or more wind projects in Nebraska. Load-flow studies were conducted to determine what transmission improvements would be necessary for a 50 MW wind plant and a 200 MW wind plant to be developed at five locations in Nebraska and to transmit the output out of Nebraska. The NPA estimated transmission cost improvements would range from \$80 to \$185 per kilowatt of installed wind capacity. The NPA concluded that it would not be economically feasible to pursue a public power entrepreneurial venture with wind power.

¹³ Gibbs, Barclay; Biewald, Bruce. *Transmitting Windpower from the Dakotas to Chicago: A Preliminary Analysis of a Hydrogen Transmission Scenario*. September 2000. Available at <http://www.energyfoundation.org/documents/NDakotaWindPower.pdf>.

¹⁴ Nebraska Power Association. *Potential for Merchant Wind Energy in Nebraska: Report of the Nebraska Power Association to Governor Mike Johanns*. February 2002. Available at <http://www.nepower.org/Pdf/NPA%20Wind%20Report%20to%20Governor%20Johanns.pdf>.

Several entities found fault with the NPA report, and the Nebraska Energy Office (NEO) commissioned a report examining alternative means of developing wind in Nebraska.¹⁵ The NEO report concluded that transmission upgrade costs would not be prohibitive if they were paid for by all customers rather than imposed on the wind generator.

Southwest Minnesota Transmission Expansion, 2003

Minnesota has been a national leader in fostering renewable energy development. The State requires Xcel Energy to have 825 MW of wind energy by 2012 (400 MW of that was required by the end of 2002, a requirement met by Xcel) and to meet 10 percent of its energy generation by 2015 from renewable energy. Other utilities in the state are under a “good faith” requirement to meet that same 10 percent target.

Almost all of the wind development in Minnesota has taken place in the southwestern part of the State, where good wind resources abound but where the transmission system is relatively weak. Xcel applied for a series of new transmission lines in order for wind energy to be developed to meet the state’s wind energy requirements. Xcel proposed three different transmission line options. The Minnesota PUC approved four transmission lines:

- A 161-kV transmission line in Jackson and Marin counties in Minnesota
- A 345-kV transmission line connecting the Lakefield Junction Substation and the Split Rock Substation in South Dakota, the Minnesota portion of which is in Jackson, Nobles, and Rock counties
- A 115-kV line in Noble and Murray counties in Minnesota
- A 115-kV line from the Buffalo Ridge Substation in Minnesota to the White Substation in South Dakota, the Minnesota portion of which would be in Lincoln County

¹⁵ DeMeo, Ed. *Accelerating Wind Power Development in Nebraska: Status, Recommendations and Perspective*. Nebraska Energy Office, March 2003. Available at http://www.nol.org/home/NEO/reports/accel_wind.htm.

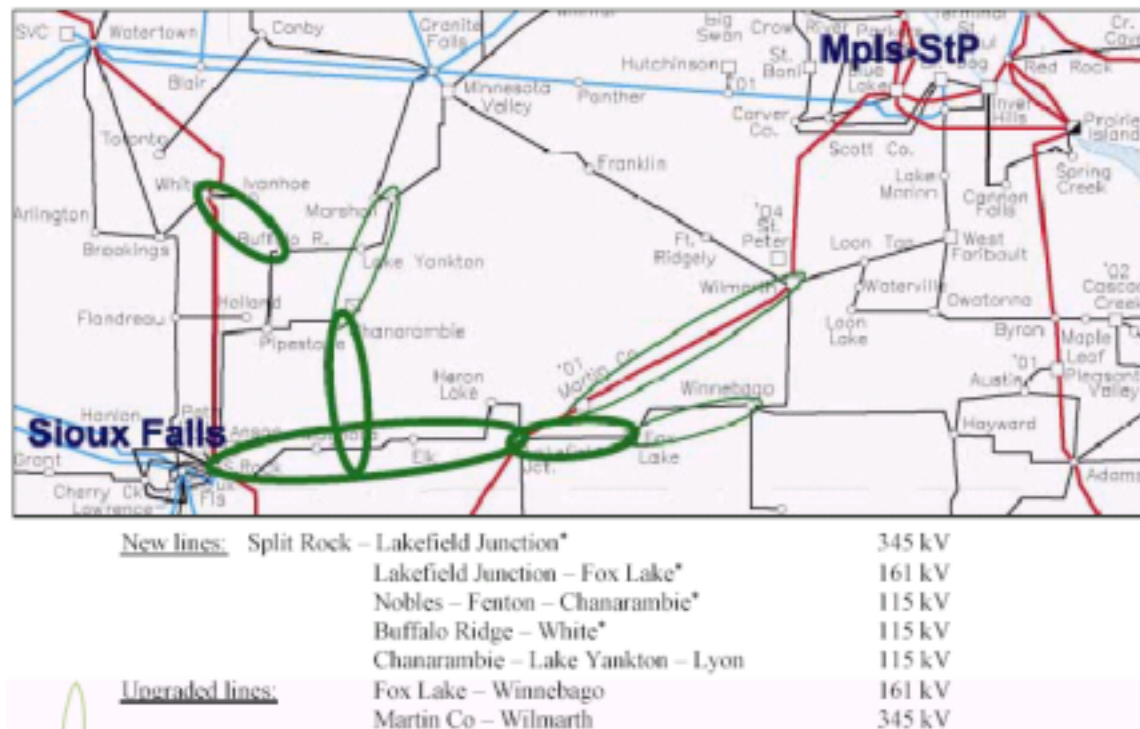


Figure 3. Approved new transmission lines in Southwestern Minnesota.

Although the intent of Xcel's application was to have sufficient transmission to meet the State's wind energy requirement, stakeholders were concerned that Federal open access transmission requirements would not allow Xcel to simply reserve the transmission outright for wind energy. They noted the new transmission would be in service by 2006, six years before Xcel had to acquire the 425 MW of wind energy to meet the second part of the State wind energy requirements and that the transmission lines built to meet those requirements would not be available when the utility procured the wind energy to meet its State requirement.

With these concerns in mind, the Minnesota PUC required Xcel Energy to purchase the additional 425 MW of wind by 2006 instead of 2012, to have no less than 675 MW of wind under contract or in operation by the end of 2003, and to designate the wind capacity as network resources under the Midwest Independent System Operator's (ISO's) Open Access Transmission Tariff. Of the overall 825 MW, 60 MW must be from local wind projects owned by farmers, communities, and small businesses in southwest Minnesota.¹⁶

¹⁶ Minnesota Public Utilities Commission. *In the Matter of the Application of Northern States Power Co. d/b/a Xcel Energy for Certificates of Need for Four Large High Voltage Transmission Line Projects in Southwestern Minnesota*, Docket No. E-002/CN-01-1958, March 11, 2003. Available at http://www.solpath.com/luna/admin/documents/345_Order.pdf.

Midwest ISO, Midwest Transmission Expansion Plan (MTEP '03), June 2003

The Midwest Independent System Operator (MISO) operates a significant part of the upper Midwest transmission system. The Federal Energy Regulatory Commission (FERC) approved MISO as one of the only two regional transmission organizations in the country.¹⁷ MISO coordinates the transmission operations and planning of 27 upper Midwest utilities and one Canadian utility. The area MISO covers includes more than 100 GW of electric demand; 122 GW of electric generating capacity; and more than 100,000 miles of transmission lines that go from Manitoba, Canada, to Kentucky.

MISO performs a system-wide transmission plan biennially, called the Midwest Transmission Expansion Plan (MTEP). MISO published its first five-year transmission plan in June 2003, covering 2002 through 2007.¹⁸ The plan is the result of a collaborative process with MISO transmission owners, transmission customers, regulatory agencies, and interested stakeholders. Transmission owners are responsible for developing their transmission system-specific plans. The plans are then coordinated by MISO in crafting the MTEP. In addition to plans from transmission owners, MISO incorporates information from regional planning groups such as MAPP; plans associated with customer requests for firm transmission service; studies from generator interconnection requests; plans developed by MISO to meet intra-regional needs; and plans developed by MISO with other ISOs to meet inter-regional needs.

MTEP '03 includes a traditional utility transmission planning component that identifies transmission improvements necessary to meet load growth, requests for transmission service, and to interconnect new generation with known commitments. MISO characterizes its plan as reliably meeting present and future demand for electric power, with nominal upgrades to interconnect new generators but with few regional expansions of transmission capacity. Overall, MISO endorsed \$1.364 billion in planned transmission projects and \$471 million in proposed transmission projects through 2007, with 85 percent devoted to lower voltage transmission lines defined at 230 kV or less. MISO acknowledged that even with these recommended improvements, transmission congestion will persist. As a result, requests for new transmission service may be denied, and existing transmission service may be curtailed at times. These denials and curtailments translate into redispatch costs from transmission congestion.¹⁹

MTEP '03 also contains a forward-looking analysis that examines potential transmission expansion scenarios that could access other generation sources, lower wholesale energy costs, and potentially relieve transmission congestion. MISO did this analysis using a production cost simulation that projects location-specific prices that would occur in a bid-

¹⁷ The Pennsylvania-New Jersey-Maryland grid (PJM) is the other FERC-approved RTO.

¹⁸ Midwest Independent System Operator. *MTEP-03: Midwest ISO Transmission Expansion Plan 2003*. June 19, 2003. Available at http://www.midwestiso.org/plan_inter/documents/expansion_planning/MTEP%202002-2007%20Board%20Approved%20061903.pdf.

¹⁹ Redispatch means that higher cost generation must be delivered to customers over lower cost generation that is blocked because of transmission congestion.

based energy market. MISO evaluated four generation scenarios—baseline, higher natural gas, higher coal, and high wind—against 11 transmission scenarios. For the wind scenario, MISO used the Midwest Wind Development by AWEA and Wind on the Wires, a stakeholder group aimed at developing new transmission for wind projects in the Midwest. That plan called for 10,000 MW of wind at various points in the Midwest to serve metropolitan areas.

		MW (nameplate)	Injection Point (existing substation)		Market	Wind Class	Net Annual Cap. Factor ¹	Busbar Cost (\$/MWh) ²
Illinois	North	300	Nelson	115/345 kV	Chicago	4±	30%	25-30
	Central	300	Brokaw	115/345 kV	Chicago/St. Louis	4±	30%	25-30
Iowa	North	1200	Spencer	161 kV	Chicago-Milwaukee	4-5	35%	23-27
			Hancock	161 kV	Chicago-Milwaukee	4-5	35%	23-27
			Adams	161/345 kV	Chicago-Milwaukee	4-5	35%	23-27
			Sac	161 kV	Des Moines	4-5	35%	23-27
			Webster	161/345 kV	Cedar Rapids	4-5	35%	23-27
Kansas	East South Central	200 400	Eureka	115 kV	St. Louis/Kansas City/Topeka	4±	30%	25-30
			Cudahy	115 kV	Wichita/Kansas City/St. Louis	4±	30%	25-30
			Dodge City	115 kV	Wichita/Kansas City/St. Louis			
Minnesota	Southwest*	1200	Elk	161 kV	Minneapolis-St. Paul	4-5	35%	23-27
			Chanarambie	115 kV	Minneapolis-St. Paul	4-5	35%	23-27
			Buffalo Ridge	115 kV	Minneapolis-St. Paul	4-5	35%	23-27
			White	115/345 kV	Minneapolis-St. Paul	4-5	35%	23-27
			Watertown	230/345 kV	Minneapolis-St. Paul	4-5	35%	23-27
Nebraska	North Central	100	Ainsworth	115 kV	Omaha/Lincoln	4±	30%	25-30
Oklahoma	Northwest	150	Gayman	115 kV	Kansas City/St. Louis	4±	30%	25-30
	North Central	150	Chickaskia	115 kV	Tulsa	4±	30%	25-30
North Dakota	Central	300	Coal Creek	230/345 kV	Minneapolis-St. Paul	4-5	35%	23-27
	South Central	200	Ellendale	115/230 kV	Minneapolis-St. Paul	5-6	40%	20-25
	East	150	Pickert	230 kV	Minneapolis-St. Paul	4±	30%	25-30
South Dakota	Central	300	Ft. Thompson	230/345 kV	Chicago-Milwaukee	5-6	40%	20-25
	Southeast	250	Split Rock	115/345 kV	Sioux Falls/Minneapolis-St.P	4±	30%	25-30
	South Central	100	Mission	115 kV	Sioux Falls/Minneapolis-St.P	5-6	40%	20-25
Wisconsin	Southwest	200	Darlington	115 kV	Chicago-Milwaukee	3±	20%	50-55
TOTAL		5500						

Additional new wind power for high transmission case:

North Dakota	Central	2250	Coal Creek	345/230 kV	Minneapolis-St. Paul	4-5	35%	20-25
South Dakota	Central	2250	Ft. Thompson	345/230 kV	Chicago-Milwaukee	5-6	40%	15-20
TOTAL		4500						

Notes:

1. Net Annual Capacity Factor - includes reductions for collector system & transformer losses, availability losses, array losses, etc.
2. Projected 2007 busbar cost; 30 year levelized cost in constant 2002 \$; includes the Production Tax Credit.

Figure 4: Potential wind capacity by State, 2003-2007, from the Wind Development Plan.

MISO determined that under the high wind scenario, lower marginal costs of wholesale energy may be realized as long as additional transmission investment is made, but that the cost-benefit ratio of that potential investment warranted additional study. MISO did this analysis at natural gas prices of \$3.50 per mmBTU and a “high” natural gas price scenario of \$5 per mmBTU (was considered high at the time but is currently about the national average for natural gas prices). Although the transmission additions may be

costly, they would allow access to lower cost resources that would offset the cost of the transmission additions and lower overall costs to electric customers. Two of the scenarios are relevant to wind. The Northwest 345-kV expansion and Dakota 500-kV line would bring in new coal and wind resources from North and South Dakota, while the Iowa and southwest Minnesota scenario would also access good wind resources and resolve some chronic transmission constraints in the region.

The Conference Report for the Omnibus Appropriations Act for Fiscal Year 2004 (H.R. 108-401) also identified a wind energy transmission study to be undertaken by Basin Electric Cooperative that is only just starting.

Input from Transmission Providers in the Upper Midwest

EERE staff contacted 25 upper Midwest transmission planners, 17 transmission providers, various representatives of the wind industry, and Indian tribes in the region, regarding this report. As noted at the beginning of the report, EERE asked them for input on the following:

1. The geographical scope of the analysis, i.e., which States compose the upper Midwest.
2. The proposed scope of the analysis.
3. The identification of ongoing studies to support wind and other transmission requirements.
4. The transmission studies needed to fill gaps.

Most of the responses that EERE received supported the geographic scope and approach of the analysis. One respondent thought the report should include Kansas City and St. Louis instead of the Twin Cities of Minneapolis/St. Paul and Chicago and Milwaukee. This person felt that not expanding the geographic span could limit the analysis to power deliveries from the windy areas in the western part of the upper Midwest to the east, whereas there may be equivalent or larger market potential in the south.

Regarding transmission, it was noted that the upper Midwest transmission is generally characterized by generation located far from electric demand, leading to transmission constraints caused by stability and voltage collapse. Because the best wind resources in the region are also relatively far from electric demand, significant wind development in the region could aggravate this situation.

Respondents from Indian tribes noted that reservations are located on some of the best wind resources in the country. The tribes would like assistance with interconnecting a number of small wind projects on tribal lands in the upper Midwest. They also pointed out that transmission in the upper Midwest is well interconnected from north to south, but these transmission lines are not always interconnected from east to west. This “no man’s land” of limited east-west transmission capacity runs through parts of Illinois, Iowa, Minnesota, and Wisconsin.

One transmission planner recognized the previous work done by MISO, but believed the MISO exploratory analysis was primarily a financial analysis that indicated wholesale customers would benefit from adding transmission capacity. It was suggested that MISO did not determine if their analysis would result in a reliable transmission plan and that more ground-level transmission work needs to be done to accommodate the wind generation scenario embodied in MISO's MTEP '03. The studies might include determination of minimum local generation in metropolitan markets, such as the Twin Cities, to ensure enough local inertia and reactive power exists to support the importation of significant wind power without local stability or voltage collapse and a system stability analysis. Another respondent suggested that more studies are not necessary, but that political will and government policies are needed to help facilitate the construction of more transmission facilities. Although transmission planners have identified the need for more transmission for many years, very few have been built. It was also suggested that it would be more efficient to consolidate the numerous studies currently conducted.

In terms of relevant transmission studies, the respondents identified many of the studies summarized in this report, as well as the various MISO exploratory transmission scenarios. One transmission planner noted that there are several local studies regarding proposed new wind projects in southwestern Minnesota and Northwestern Iowa. In addition, the Minnesota Department of Commerce is undertaking a study on integrating large amounts of wind in a utility control area in response to a requirement passed by the Minnesota Legislature in 2003. Representatives from Indian tribes referred to an NREL report, *Wind Development Options for Native Americans in the Dakotas*, that identifies potential wind sites on Indian lands near WAPA transmission lines and substations. The Indian tribe representatives also referred to a report from the U.S. Energy Information Administration, *Energy Consumption and Renewable Energy Development Potential on Indian Lands*. The representatives expressed interest in an analysis of wind project potential near WAPA or other utility transmission lines on Indian lands in the Upper Midwest, using the early WAPA studies as an example.

Various wind representatives said the National Wind Coordinating Council's (NWCC) Midwest transmission workshops helped to bring transmission planners and the wind industry together. The Wind Development Plan that provided input into MISO's wind scenario in MTEP '03 was a result of these meetings. The representatives also said the NWCC transmission planning principles represent the consensus of wind industry, environmental groups, transmission planners, and state regulators.²⁰

²⁰ The NWCC transmission planning principles can be viewed at http://www.nationalwind.org/pubs/Transmission_Planning_Principles.pdf.

Conclusions

- The upper Midwest has very large wind resources, with five of the top ten States in terms of wind resource located in this region.
- Generally, the best wind resources in the upper Midwest are in more remote, less-populated areas far from metropolitan areas that have a higher demand for electricity. Current wind economics favor more remote wind resources, even when factoring in incremental transmission costs to transmit the wind energy to metropolitan centers
- Transmission in the upper Midwest is generally constrained. In addition, because power generation is often transmitted over long distances to metropolitan centers, the upper Midwest has voltage and stability issues that must be considered.
- Large-scale wind development will generally require additional transmission capacity. Wind projects to serve local electric demand, such as the Basin Electric wind projects in North Dakota and South Dakota, may not require additional transmission capacity.
- Although MISO issued a transmission plan in 2003 that recommends up to \$1.862 billion in transmission improvements to maintain reliability, it acknowledged these improvements will not address the upper Midwest transmission constraints.
- As a relatively new organization, MISO's current transmission plans are primarily an accumulation of the transmission and resource plans of individual participants, a bottom-up effort, and is only to a lesser degree at this time a strategic MISO-region wide synthesis of this information, which would be a more top-down approach. DOE supports and encourages MISO's efforts to move toward top-down, region-wide transmission planning with sensitivities focusing on transmission system implications for different regional resource deployment strategies.
- MISO is exploring potential transmission expansion options that, if implemented, could resolve some of the region's transmission constraints and access lower cost wholesale energy resources, including wind. However, the question of who pays for transmission expansions continues to be a major barrier to large-scale exploitation of the abundant wind (and coal) resources in the upper Midwest. Until the question of who pays (which included issues of cost recovery and cost allocation) is answered, there can be no major expansion of transmission capacity to support wind energy development in the Upper Midwest.

- Joint use of new transmission capacity by remote wind and coal resources should continue to be explored in the upper Midwest. Combined, coal and wind generation could help maximize utilization of transmission lines and thus improve overall project economics, while the wind plant output partially offsets coal plant emissions.
- Long-distance transmission expansion may take several years to permit and build. Interest has been expressed in short-term and mid-term options such as strategic upgrades at key constrained locations and tariff changes, such as flexible firm transmission service, that could make more transmission available.
- Transmission planners identified some needed information and studies. DOE and the wind industry can provide the information identified by transmission planners to ensure that wind energy can be integrated into the electric system.